EXPERIMENTS IN PERCEPTION

by W. H. ITTELSON & F. P. KILPATRICK

REPRINTED FROM
SCIENTIFIC AMERICAN
AUGUST 1951

PUBLISHED BY W. H. FREEMAN AND COMPANY 660 MARKET STREET, SAN FRANCISCO 4, CALIFORNIA

Experiments in Perception

Some remarkable optical illusions show that what we perceive does not directly correspond to reality; it is a subtle blend of the external world and the many lessons of our experience

by W. H. Ittelson and F. P. Kilpatrick

WHAT is perception? Why do we see what we see, feel what we feel, hear what we hear? We act in terms of what we perceive; our acts lead to new perceptions; these lead to new acts, and so on in the incredibly complex process that constitutes life. Clearly, then, an understanding of the process by which man becomes aware of himself and his world is basic to any adequate understanding of human behavior. But the problem of explaining how and why we perceive in the way we do is one of the most controversial fields in psychology. We shall describe here some recent experimental work which sheds new light on the problem and points the way to a new theory of perception.

The fact that we see a chair and are then able to go to the place at which we localize it and rest our bodies on a substantial object does not seem particularly amazing or difficult to explain—until we try to explain it. If we accept the prevailing current view that we can never be aware of the world as such, but only of the nervous impulses arising from the impingement of physical forces on sensory receptors, we immediately face the necessity of explaining the correspondence between what we perceive and whatever it is that is there.

An extremely logical, unbeatable—and scientifically useless—answer is simply to say there is no real world, that everything exists in the mind alone. Another approach is to postulate the existence of an external world, to grant that there is some general correspondence between that world and what we perceive and to seek some understandable and useful explanation of why that should be. Most of the prominent theories about perception have grown out of the latter approach. These theories generally agree that even though much of the correspondence may be due to learning, at some basic level there exists an absolute correspondence between what is "out there" and what is in the "mind." But there is a great deal of disagreement concerning the level at which such innately determined correspondence occurs. At one extreme are theorists who believe that the correspondence occurs at the level of simple sensations, such as color, brightness, weight, hardness, and so on, and that out of these sensations are compounded more complex awarenesses, such as the recognition of a pencil or a book. At the other extreme are Gestalt psychologists who feel that complex perceptions such as the form of an object are the result of an inherent relationship between the properties of the thing perceived and the properties of the brain. All these schools seem to agree, however, that there is some perceptual level at which exists absolute objectivity; that is, a one-to-one correspondence between experience and reality.

This belief is basic to current thinking in many fields. It underlies most theorizing concerning the nature of science, including Percy W. Bridgman's attempt to reach final scientific objectivity in the "observable operation." In psychology one is hard put to find an approach to human behavior which departs from this basic premise. But it leads to dichotomies such as organism *v.* environment, subjective *v.* objective. Stimuli or stimulus patterns are treated as though they exist apart from the perceiving organism. Psychologists seek to find mechanical relationships or interactions between the organism and an "objectively defined" environment. They often rule out purposes and values as not belonging in a strictly scientific psychology.

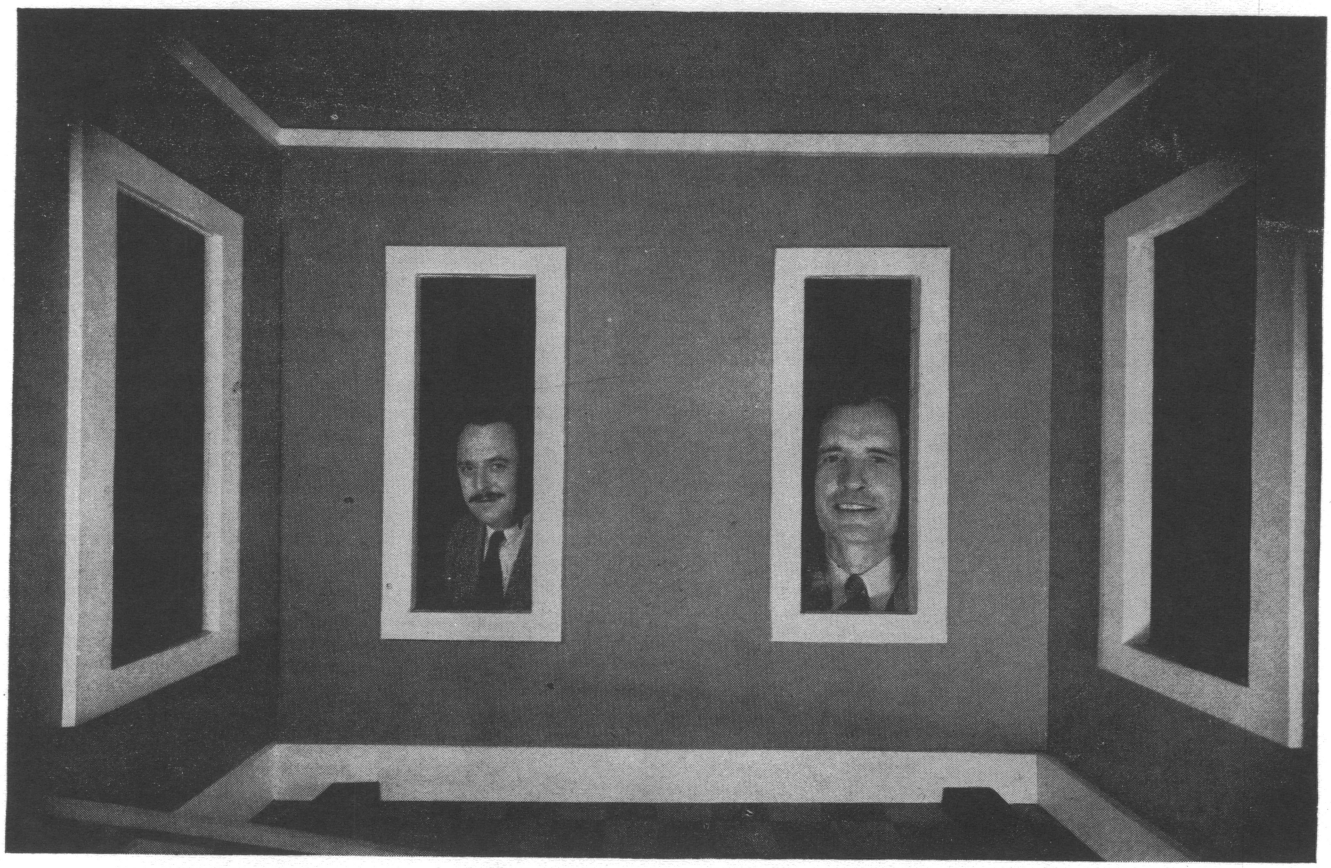
THE experiments to be described here arose from a widespread and growing feeling that such dichotomies are false, and that in practice it is impossible to leave values and purposes out of consideration in scientific observation. The experiments were designed to re-examine some of the basic ideas from which these problems stem.

During the past few years Adelbert Ames, Jr., of the Institute for Associated Research in Hanover, N. H., has designed some new ways of studying visual perception. They have resulted in a new conception of the nature of knowing and of observation. This theory neither denies the existence of objects nor proposes that they exist in a given form independently, that is, apart from the perceiving organism. Instead, it suggests that the world each of us knows is a world created in large measure from our experience in dealing with the environment.

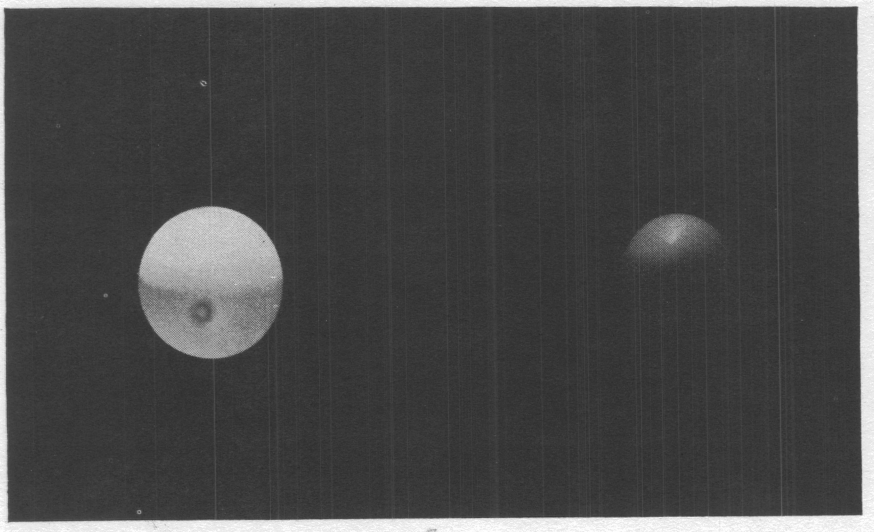
Let us illustrate this in specific terms through some of the demonstrations. In one of them the subject sits in a dark room in which he can see only two star points of light. Both are equidistant from the observer, but one is brighter than the other. If the observer closes one eye and keeps his head still, the brighter point of light looks nearer than the dimmer one. Such apparent differences are related not only to brightness but also to direction from the observer. If two points of light of equal brightness are situated near the floor, one about a foot above the other, the upper one will generally be perceived as farther away than the lower one; if they are near the ceiling, the lower one will appear farther away.

A somewhat more complex experiment uses two partly inflated balloons illuminated from a concealed source. The balloons are in fixed positions about one foot apart. Their relative sizes can be varied by means of a lever control connected to a bellows, and another lever controls their relative brightness. When the size and brightness of both balloons are the same, an observer looking at them with one eye from 10 feet or more sees them as two glowing spheres at equal distances from him. If the brightnesses are left the same and the relative sizes are changed, the larger balloon appears to nearly all observers somewhat nearer. If the size lever is moved continuously, causing continuous variation in the relative size of the balloons, they appear to move dramatically

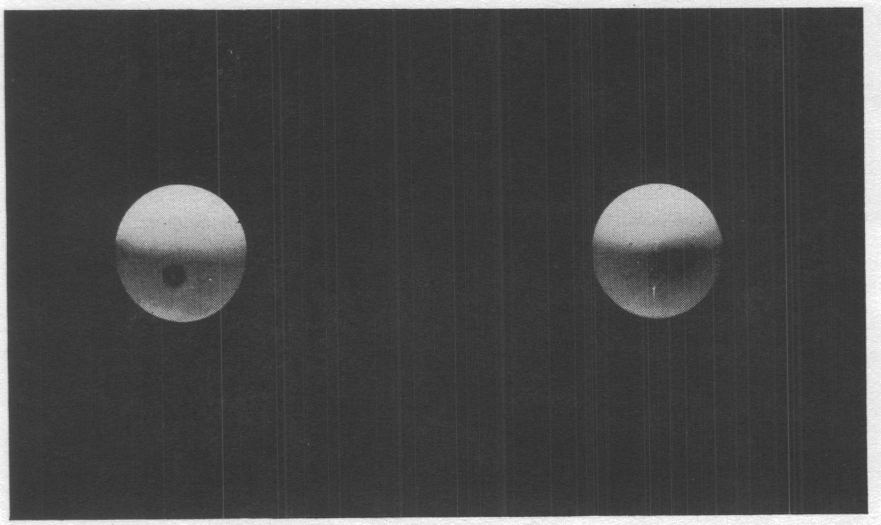
FIGURES ARE DISTORTED when they are placed in a specially constructed room. The woman at left appears much smaller than the one at right because the mind "bets" that the opposite surfaces of the room are parallel.



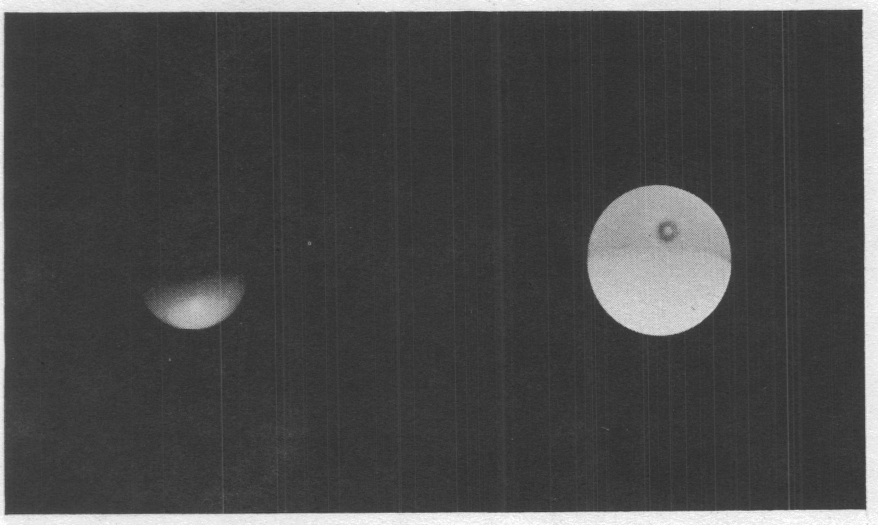
HEADS ARE DISTORTED by the same process. The head of the man at the left appears to be much smaller than the head of the man at the right because the mind assumes that all the windows are the same height.



LEFT BALLOON APPEARS CLOSER because it is larger and brighter than the balloon at the right. Both balloons, however, are at same distance.



BALLOONS APPEAR EQUIDISTANT when they are the same size and brightness. The qualities are manipulated with levers in the demonstration.



RIGHT BALLOON APPEARS CLOSER when it is larger and brighter. The demonstration shows that size and brightness are cues for distance.

back and forth through space, even when the observer watches with both eyes open. The result is similar when the sizes are kept equal and the relative brightness is varied.

With the same apparatus the effects of size and brightness may be combined so that they supplement or conflict with each other. When they supplement each other, the variation in apparent distance is much greater than when either size or brightness alone is varied. When conflict is introduced by varying size and brightness in opposition to each other, the relative change in distance is considerably less than when they act in combination or alone. Most people, however, give more weight to relative size than they give to brightness in judging distance.

THESE phenomena cannot be explained by referring to "reality," because "reality" and perception do not correspond. They cannot be explained by reference to the pattern in the retina of the eye, because for any given retinal pattern there are an infinite number of brightness-size-distance combinations to which that pattern might be related. When faced with such a situation, in which an unlimited number of possibilities can be related to a given retinal pattern, the organism apparently calls upon its previous experiences and assumes that what has been most probable in the past is most probable in the immediate occasion. When presented with two star-points of different brightness, a person unconsciously "bets" or "assumes" that the two points, being similar, are probably identical (*i. e.*, of equal brightness), and therefore that the one which seems brighter must be nearer. Similarly the observed facts in the case of two star-points placed vertically one above the other suggest that when we look down we assume, on the basis of past experience, that objects in the lower part of the visual field are nearer than objects in the upper part; when we look up, we assume the opposite to be true. An analogous explanation can be made of the role of relative size as an indication of relative distance.

Why do the differences in distance seem so much greater when the relative size of two objects is varied continuously than when the size difference is fixed? This phenomenon, too, apparently is based on experience. It is a fairly common experience, though not usual, to find that two similar objects of different sizes are actually the same distance away from us. But it is rare indeed to see two stationary objects at the same distance, one growing larger and the other smaller; almost always in everyday life when we see two identical or nearly identical objects change relative size they are in motion in relation to each other. Hence under the experimental conditions we

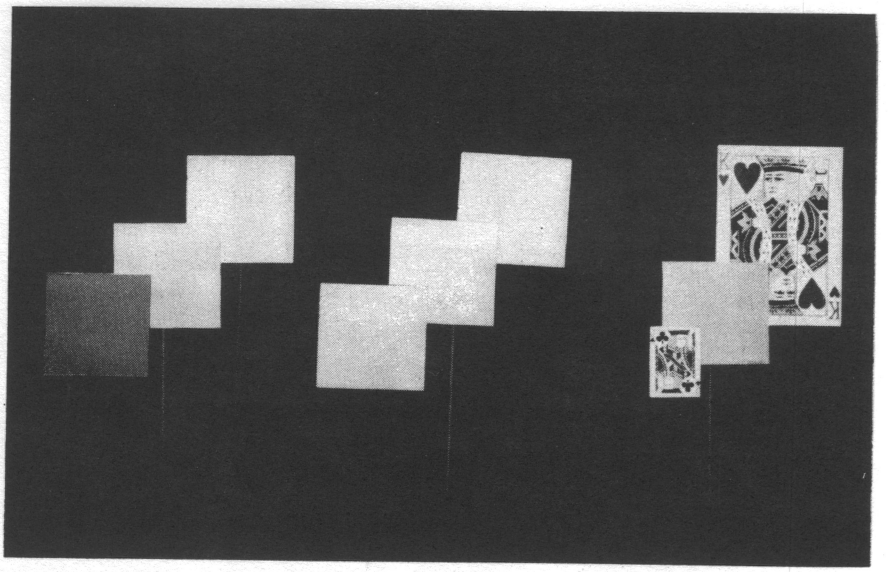
are much more likely to assume distance *differences* in the objects of changing size than in those of fixed size. In other words, apparently we make use of a weighted average of our past experience in interpreting what we see. It seems that the subject relates to the stimulus pattern a complex, probability-like integration of his past experience with such patterns. Were it not for such integrations, which have been labeled assumptions, the particular perceptual phenomenon would not occur. It follows from this that the resulting perceptions are not absolute revelations of "what is out there" but are in the nature of probabilities or predictions based on past experience. These predictions are not always reliable, as the demonstrations make clear.

VISUAL perception involves an impression not only of *where* an object is but of *what* it is. From the demonstrations already described we may guess that there is a very strong relationship between localization in space ("thereness") and the assignment of objective properties ("thatness"). This relationship can be demonstrated by a cube experiment.

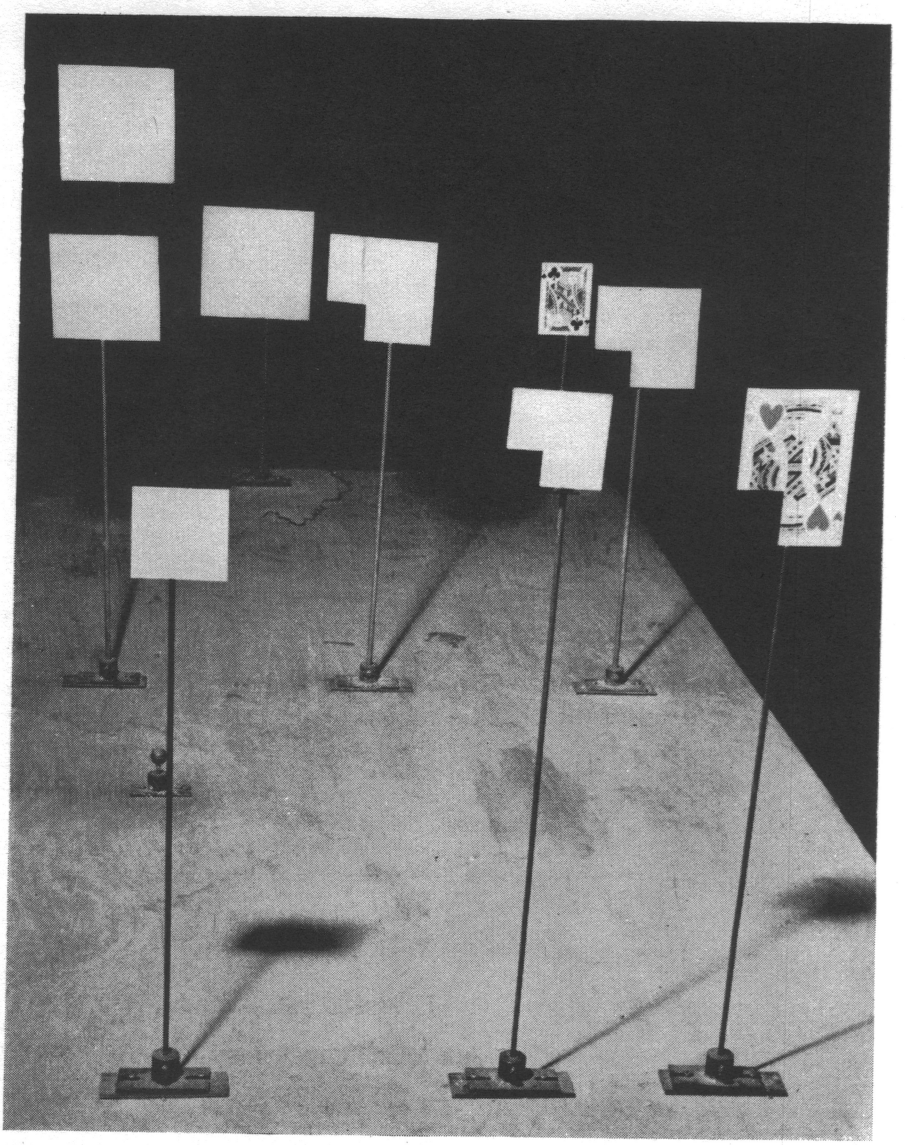
Two solid white cubes are suspended on wires that are painted black so as to be invisible against a black background. One cube is about 3 feet from the observer and the other about 12 feet. The observer's head is in a headrest so positioned that the cubes are almost in line with each other but he can see both, the nearer cube being slightly to the right. A tiny metal shield is then placed a few inches in front of the left eye. It is just big enough to cut off the view of the far cube from the left eye. The result is that the near cube is seen with both eyes and the far cube with just the right eye. Under these conditions the observer can fix the position of the near cube very well, because he has available all the cues that come from the use of the two eyes. But in the case of the far cube seen with only one eye, localization is much more difficult and uncertain.

Now since the two cubes are almost in line visually, a slight movement of the head to the right will cause the inside vertical edges of the cubes to coincide. Such coincidence of edge is strongly related to an assumption of "togetherness." Hence when the subject moves his head in this way, the uncertainly located distant cube appears to have moved forward to a position even with the nearer cube. Under these conditions not only does the mislocated cube appear smaller, but it appears different in shape, that is, no longer cubical, even though the pattern cast by the cube on the retina of the eye has not changed at all.

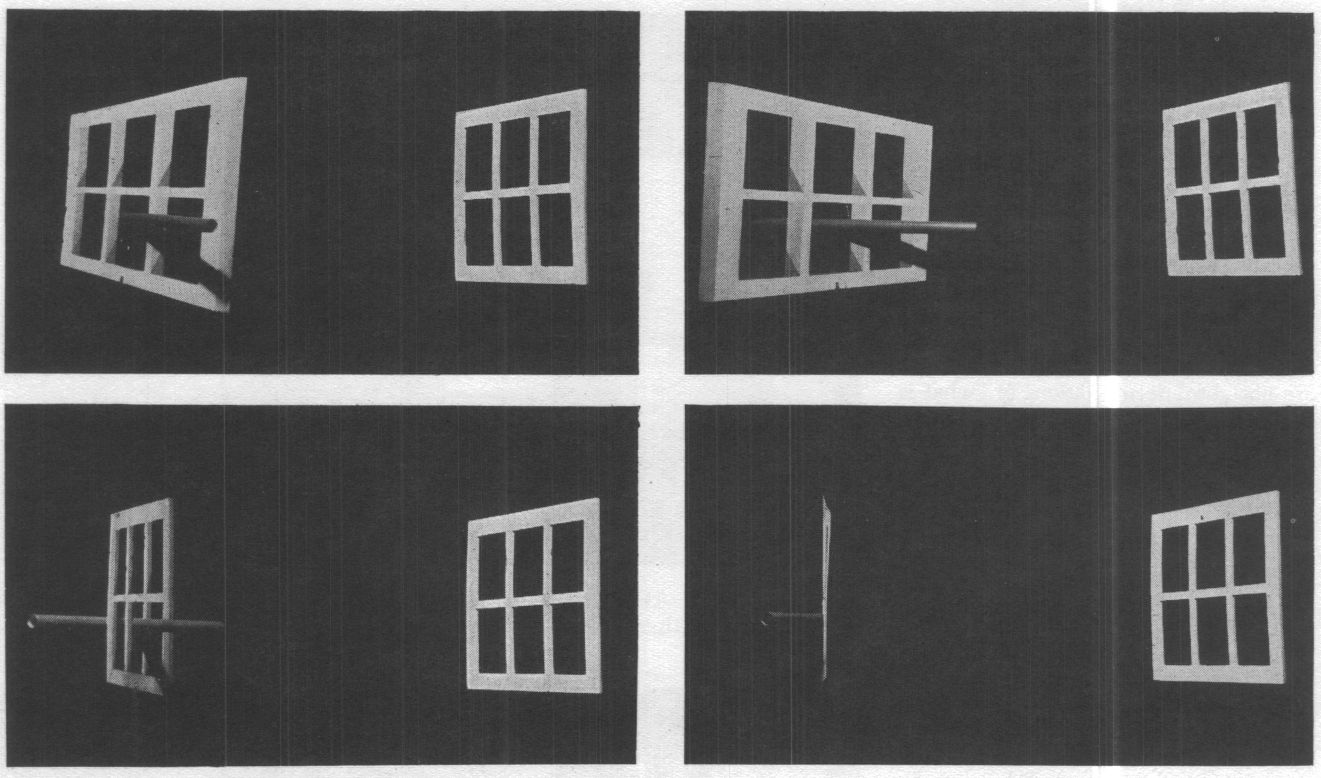
The same point can be illustrated most dramatically by experiments in which the subject wears a pair of glasses



LEFT CARDS APPEAR CLOSER than those at the center and right in each of the three rows in this picture. The illusion is revealed below.



RIGHT CARDS ARE CLOSER in the rows at the center and right. Here the cues are size and the fact that the cards appear to overlap.



PERCEPTION OF MOVING OBJECTS was investigated with a rotating window. At the right in each of the eight pictures on these two pages is a rectangular window; at the left in each picture is a trapezoid painted to

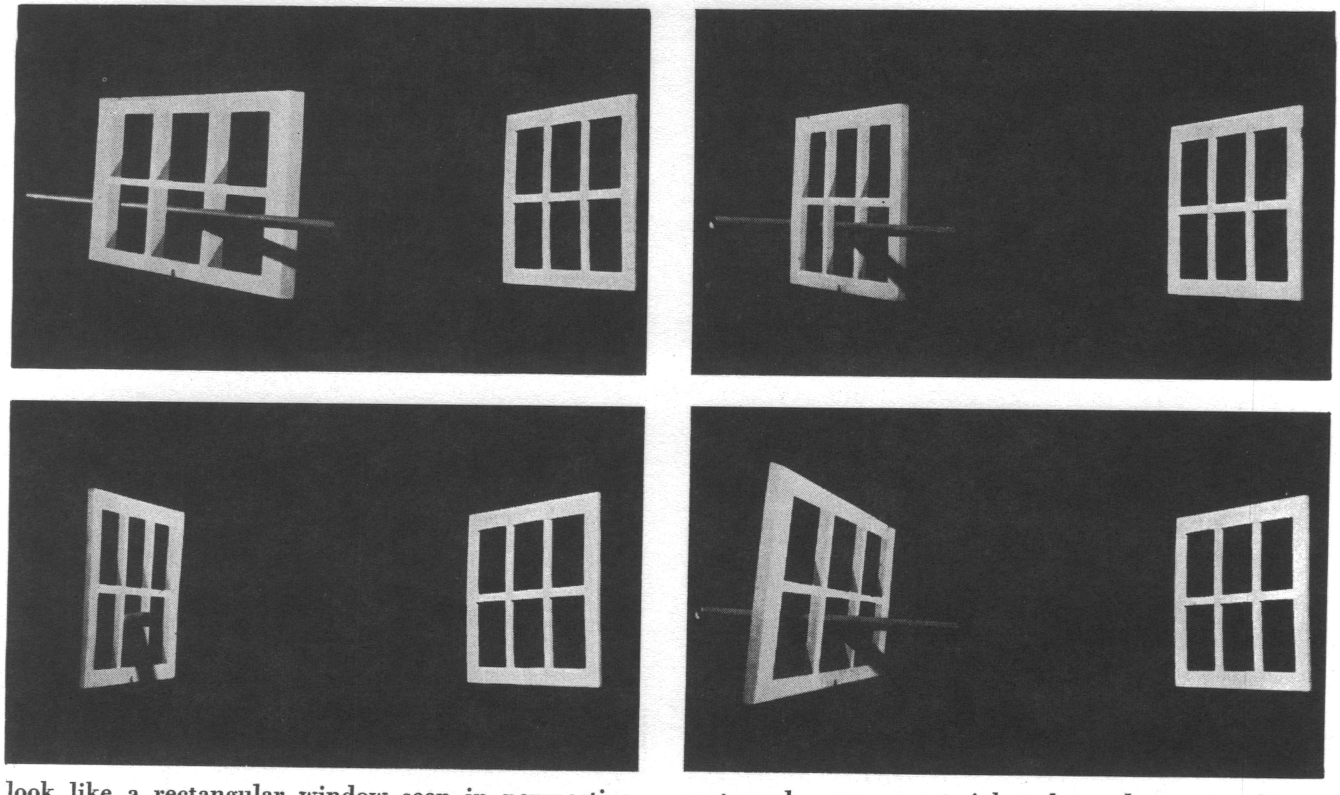
fitted with so-called aniseikonic lenses, which are ground in such a way that they give images of different size and shape to the two retinas. This produces very marked distortions of any objects which the subject visualizes mainly through the use of two-eyed stereoscopic vision. In an ordinary environment there are generally enough one-eye cues, such as shadow, overlay, familiar objects of known size, and so on, to suppress the binocular cues and hold the visual world "in shape." But in an environment poor in one-eye cues the observer is forced to rely on binocular cues, and under these circumstances the distortion is enhanced for anyone wearing such glasses. It has been found that if an ordinary square room is lined with tree leaves, which reduce monocular cues to a minimum by covering the flat wall spaces, most observers looking through aniseikonic lenses perceive a great deal of distortion of the room and the leaves. To an observer looking at the room as a whole through certain glasses of this type the walls appear to slant inward from floor to ceiling, the ceiling seems much lower than it is and its leaves look very small. The floor, which is the object of interest in this particular analysis, appears to be much farther away than its true position, and the leaves covering it look huge. Now, if the observer wearing the same glasses looks at just the floor instead of the room in general, the floor changes markedly in appearance. It appears to be much nearer than before, and instead of being level it seems to rise from front to back at a pitch of about 45 degrees. The leaves, however, now look more nearly normal in size.

THESE perceptions can be explained in terms of the geometry of stereoscopic vision. The stimulus patterns on the retinas of the eyes are the geometric projections of an external surface. But identical projections may be produced by surfaces of different kinds. In this case a distant surface that is nearly horizontal, a closer surface that is slightly tipped and a very near surface that is sharply tipped all produce the same steroscopic stimulus patterns. When the observer looks at the whole room, he "chooses" the nearly horizontal faraway floor surface as the focus of perception, probably because he cannot make a room out of the pattern if the floor is sharply tipped up. When he limits his gaze to the floor, he no longer needs to make a room of what he is looking at, and he sees the floor sharply tipped, perhaps because the leaves now appear more nearly the size he assumes them to be.

In the everyday environment outside the laboratory the wearing of these glasses produces similarly interesting illusions. For example, a large body of water such as a lake appears horizontal and farther away than its real position, but a large expanse of level lawn looks tipped and nearer than its real position. Presumably this happens because the observer brings to these occasions the assumptions, based on past experience, that the probability of a lake surface being other than horizontal is almost zero, while the probability of a grass surface being a slope is fairly high.

The most reasonable explanation of these visual phenomena seems to be that an observer unconsciously relates to the stimulus pattern some sort of weighted average of the past consequences of acting with respect to that pattern. The particular perception "chosen" is the one that has the best predictive value, on the basis of previous experience, for action in carrying out the purposes of the organism. From this one may make two rather crucial deductions: 1) an unfamiliar external configuration which yields the same retinal pattern as one the observer is accustomed to deal with will be perceived as the familiar configuration; 2) when the observer acts on his interpretation of the unfamiliar configuration and finds that he is wrong, his perception will change even though the retinal pattern is unchanged.

Let us illustrate with some actual demonstrations. If an observer in a dark room looks with one eye at two lines of light which are at the same distance and elevation but of different lengths, the longer line will look nearer than the shorter one. Apparently he assumes that the lines are identical and translates the difference in length into a difference in position. If the observer takes a wand with a luminous tip and tries to touch first one line and then the other, he will be unable to do so at first. After repeated practice, however, he can learn to touch



look like a rectangular window seen in perspective. When the trapezoid rotates, the assumption that it is rectangular causes a straight tube to do strange things. The sequence reads horizontally across the two pages.

the two lines quickly and accurately. At this point he no longer sees the lines as at different distances; they now look, as they are, the same distance from him. He originally assumed that the two lines were the same length because that seemed the best bet under the circumstances. After he had tested this assumption by purposive action, he shifted to the assumption, less probable in terms of past experience but still possible, that the lines were at the same distance but of different lengths. As his assumption changed, perception did also.

THERE is another experiment that demonstrates these points even more convincingly. It uses a distorted room in which the floor slopes up to the right of the observer, the rear wall recedes from right to left and the windows are of different sizes and trapezoidal in shape. When an observer looks at this room with one eye from a certain point, the room appears completely normal, as if the floor were level, the rear wall at right angles to the line of sight and the windows rectangular and of the same size. Presumably the observer chooses this particular appearance instead of some other because of the assumptions he brings to the occasion. If he now takes a long stick and tries to touch the various parts of the room, he will be unsuccessful, even though he has gone into the situation knowing the true shape of the room. With practice, however, he becomes more and more successful in touching what he wants to touch with the stick. More important, he sees the room more and more in its true shape, even though the stimulus pattern on his retina has remained unchanged.

By means of a piece of apparatus called the "rotating trapezoidal window" it has been possible to extend the investigation to complex perceptual situations involving movement. This device consists of a trapezoidal surface with panes cut in it and shadows painted on it to give the appearance of a window. It is mounted on a rod connected to a motor so that it rotates at a slow constant speed in an upright position about its own axis. When an observer views the rotating surface with one eye from about 10 feet or more or with both eyes from about 25 feet or more, he sees not a rotating trapezoid but an oscillating rectangle. Its speed of movement and its shape appear to vary markedly as it turns. If a small cube is attached by a short rod to the upper part of the short side of the trapezoid, it seems to become detached, sail freely around the front of the trapezoid and attach itself again as the apparatus rotates.

ALL these experiments, and many more that have been made, suggest strongly that perception is never a sure thing, never an absolute revelation of "what is." Rather, what we see is a prediction—our own personal construction designed to give us the best possible bet for carrying out our purposes in action. We make these bets on the basis of our past experience. When we have a great deal of relevant and consistent experience to relate to stimulus patterns, the probability of success of our prediction (perception) as a guide to action is extremely high, and we tend to have a feeling of surety When our experience is limited or inconsistent, the reverse holds true. According to the new theory of perception developed from the demonstrations we have described, perception is a functional affair based on action, experience and probability. The thing perceived is an inseparable part of the function of perceiving, which in turn includes all aspects of the total process of living. This view differs from the old rival theories: the thing perceived is neither just a figment of the mind nor an innately determined absolute revelation of a reality postulated to exist apart from the perceiving organism. Object and percept are part and parcel of the same thing.

This conclusion of course has far-reaching implications for many areas of study, for some assumption as to what perception is must underly any philosophy or comprehensive theory of psychology, of science or of knowledge in general. Although the particular investigations involved here are restricted to visual perception, this is only a vehicle which carries us into a basic inquiry of much wider significance.

The Authors

WILLIAM H. ITTELSON and F. P. KILPATRICK were instructors in psychology at Princeton University when they wrote this article. Professor Hadley Cantril, their senior in the department, had revived interest in the work of Adelbert Ames, Jr., and had established a laboratory at Princeton to carry on his pioneering investigation into the psychology of perception. Ittelson is now professor of psychology at Brooklyn College, and Kilpatrick is working in research and development at National Analysts, Inc. in Philadelphia.

Bibliography

THE "WHY" OF MAN'S EXPERIENCE. Hadley Cantril. The Macmillan Company, 1950.